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UNDERGROUND NUCLEAR WASTE REPOSITORY STUDIES: PETROGRAPHY AT THE SITE OF AN IN-SITU HEATER EXPERIMENT, CREIGHTON MINE, ONTARIO

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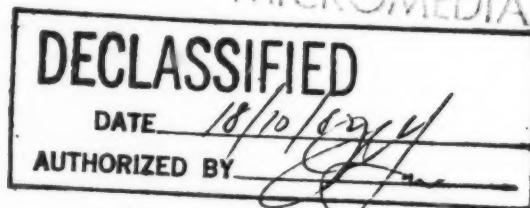
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UNDERGROUND NUCLEAR WASTE REPOSITORY STUDIES:
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by

James A. Soles*

INTRODUCTION

Prior to selection and preparation of underground repositories for long term storage or disposal of radioactive wastes from nuclear reactors⁽¹⁾, determination of the physical properties of the enclosing rocks is necessary to predict their behaviour over the required containment period and to estimate the degree of safety expected with interment.

Of particular concern is the stability of a repository under the heat load generated by decay of waste radioactive fission products. The principal properties affecting thermal stability of repository rock are thermal conductivity, diffusivity and expansion. These parameters can be obtained from direct measurements on samples of the rock, and if sampling is representative of all types present, can be used to estimate the potential thermal behaviour of the repository mass. Detailed geological information and petrographic analyses of representative rock samples are required at the same time, in order to define variables and extrapolate thermal data into areas containing similar untested material.

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This investigation involves preparation and analysis of rock from a heater experiment test site on the 2300 level of the Creighton mine of INCO Ltd., near Sudbury, Ontario. The site offers particular advantages for a fruitful study of the thermal stability of a rock mass in place: the regional geology is well known; the composition and geological structure of the site rock varies little; and the lithostatic pressure would approach that expected for a near-surface repository.

MATERIALS, PROCEDURES

The rock sample consisted of two BX (5.4 cm) drill cores extracted from the "Main Mass" norite near No. 9 mine shaft on the 2300 level. The cores were logged in detail by P. Miles of CANMET, with particular attention being paid to fracture patterns and visible discontinuities. Nine samples for the measurement of thermal conductivity, diffusivity and expansion were taken from portions of the core containing major rock types or rock of particular composition. From them, duplicate test cylinders (25.4 mm x 25.4 mm) and prisms (6.5 mm² x 50.8 mm) were cut both parallel and perpendicular to a dominant structural feature, or to the core itself when none was visible.

Thin and polished sections for petrographic analyses were prepared from adjacent material, etched with hydrofluoric acid and stained with sodium cobaltinitrite or other dyes to differentiate constituent minerals and to reveal cracks. Point count analyses were made on the sections to give modal compositions of the rock types represented.

PETROGRAPHIC INFORMATION

General Geology

The Sudbury norite is described as a phanerite of medium to coarse grain which ranges in composition from norite to quartz gabbro. Adjacent "Sub-Layer" rocks are noritic to mostly dioritic, and quartz diorite predominates in dyke-like offsets from them⁽²⁾. The rocks are considered by most petrologists to be of igneous origin⁽³⁾, perhaps magmatic differentiates, which intruded ancient tectonically disturbed clastics and granites as a massive, complex ring dyke.

Following intrusion of the norite, deformation is believed to have occurred which gave the region its present tectonic structure⁽⁴⁾. Subsequently, minor tectonic activity appears to have caused local shearing or folding and perhaps left the anisotropic horizontal stresses recently detected below 1200 m in the Creighton mine, near the heater test site⁽⁵⁾.

Petrography of Core Specimens

Descriptions of the representative samples are given below. The approximate modal analyses and grain sizes obtained from sections and test specimens are given in Table 1, and descriptive data are summarized in Table 2 to characterize the total rock mass represented by the drill cores. More detailed structural and fracture data are provided by the Miles log⁽⁶⁾.

SAMPLE CA-42 (Section LS-12-77)

The rock is a medium grained quartz diorite, greenish grey between 5G6/1 and 5B6/1⁽⁷⁾, mottled green to brown from irregularly distributed patches of amphibole and biotite. Feldspar is principally unaltered, well-twinned subhedral andesine, dusted light brown, partly rimmed with or penetrating late quartz. Scapolite, often intergrown with vermicular quartz, is also

scattered locally along the plagioclase grain boundaries. Amphibole and biotite occur in both coarse primary crystals and in fine grained intergrowths (metacrysts ?) with quartz, magnetite and feldspar (Figure 1); possibly they are deuteric alteration products of pyroxene or olivine, but no relics were observed in the sections. Accessory ilmenite and magnetite are present with the primary ferromagnesian crystals, apatite is dispersed, epidote and calcite are rare. At one point, a slickensided shear containing chloritized mylonite and scattered sulphide is adjacent to a 10-mm quartz band.

The rock texture is hypidiomorphic granular (= "granitic"); coarser phenocrysts or masses of any phase can occur locally. Quartz grains and feldspar twins appear slightly stressed and crystals in ferromagnesian intergrowths are occasionally warped, but intergranular fracturing is not evident in the sections.

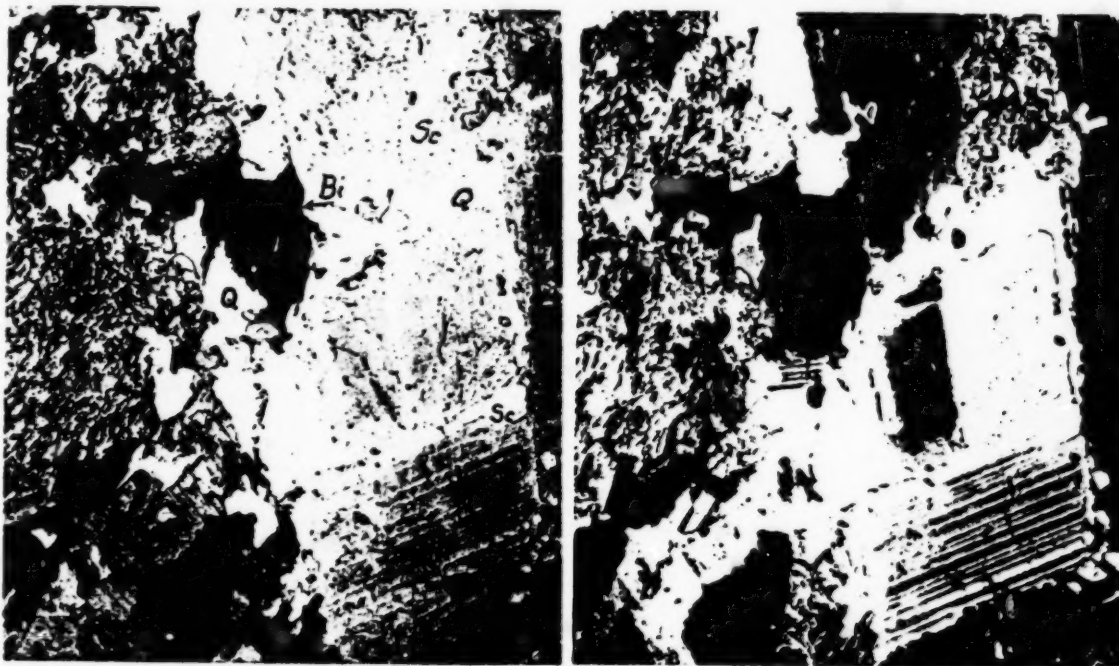


Figure 1. Photomicrograph of quartz diorite in sample CA-42 from Creighton mine, showing dusty twinned andesine subhedra with intergranular quartz (Q) and scapolite (Sc), primary biotite (Bi) and hornblende(A) with ilmenite-magnetite (black) and a secondary intergrowth of amphibole, biotite and quartz. Magnification 30x; crossed polarizers to right.

SAMPLE CA-66 (Section LS-13-77)

The specimen is compositionally and texturally similar to CA-42, but of slightly coarser grain size and darker in color. Biotite is more abundant in metacrysts, and may be intergrown occasionally with green mica or chlorite. Magnetite is often dusted through the primary amphibole crystals, which may also have darker green rims. Some warping of twin lamellae and biotite-amphibole crystals in intergrowths is apparent, suggesting stress (Figure 2), but fractures are not evident.

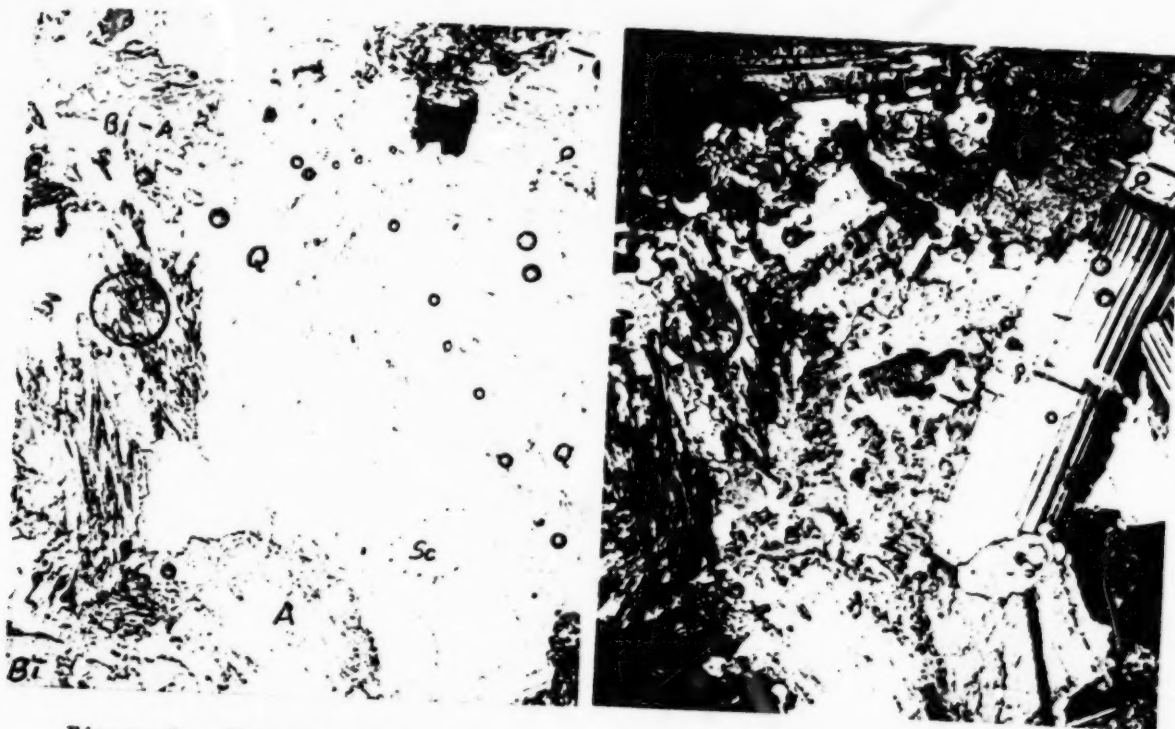


Figure 2. Photomicrograph of quartz diorite in core sample CA-66. The section shows warped twin lamellae in plagioclase and contorted amphibole-biotite intergrowths. Primary amphibole (A) has a darker green rim, perhaps actinolitic. Magnification 30x.

SAMPLE CA-79 (Section LS-14-77, LS-15-77)

The rock sample is megascopically indistinguishable from CA-42, but the scapolite content is higher and primary biotite and amphibole are

more abundant in magnetite-dusted primary crystals than in the mafic intergrowths (Figure 3).

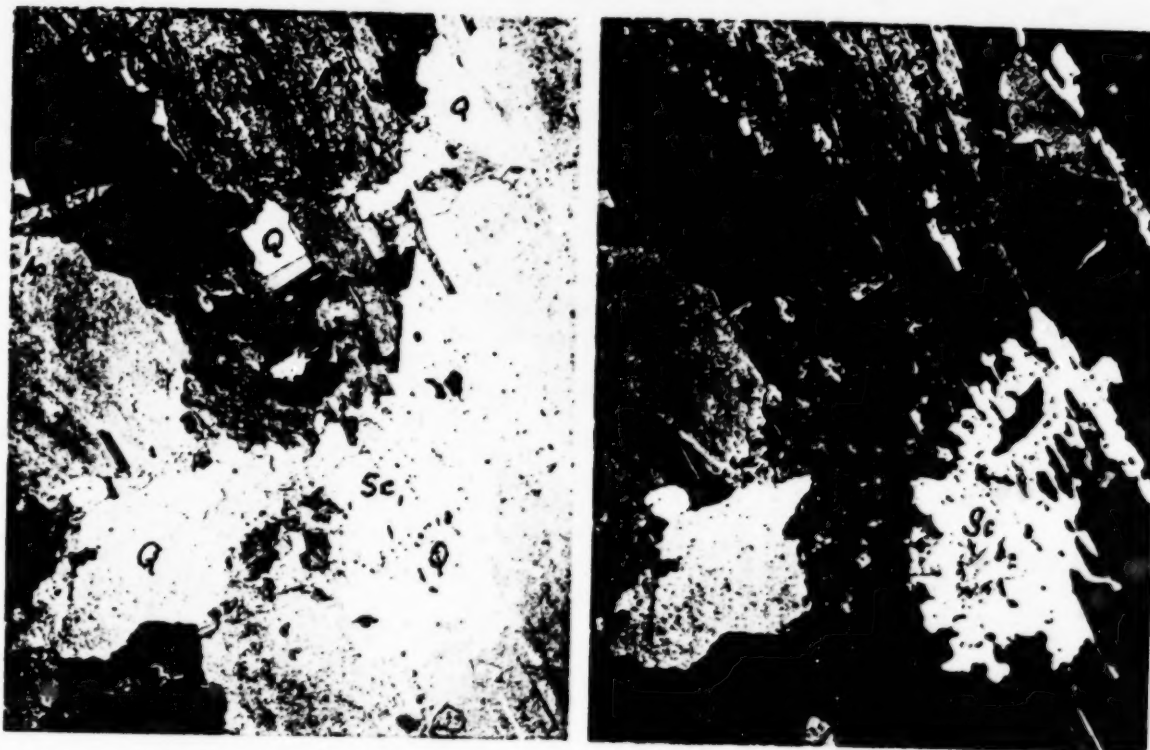


Figure 3. Quartz diorite in sample CA-79, showing scapolite in and along feldspar grain boundaries, intergranular quartz and primary amphibole and biotite crystals, which predominate over intergrowths. Ilmenite-magnetite (black) and apatite (Ap) are scattered. Magnification 30x.

SAMPLE CA-93 (Sections LS-11-77, LS-12-77)

Rock in this sample is a pale greenish grey quartz diorite, similar to CA-42 but coarser, contains more feldspar locally and, like CA-79, primary amphibole and biotite crystals are more common than intergrowths.

SAMPLE CB-32 (Sections LS-16-77, LS-17-77)

Rock at this position in the CB core is medium to fine grained, greenish grey quartz diorite much similar to that in CA-66. Well-twinned, slightly dusty andesine subhedra are randomly dispersed with primary crystals

of amphibole (hornblende), biotite and fine-grained amphibole-biotite-quartz-magnetite intergrowths possible pseudomorphous after pyroxene (Figure 4).

Interstitial quartz is fine grained, as is scapolite; it occurs also as larger blue augen and rarely in thin seams. Multi-crystal biotite is also present in large, scattered patches. Ilmenite and magnetite are scattered through the primary ferromagnesian as in CA-42.

Textural relations between minerals is the same as that in the CA core specimens, i.e., hypidiomorphic granular. One unsealed fracture with a stained surface was observed at about CB-33.6; otherwise, the core rock appears sound.

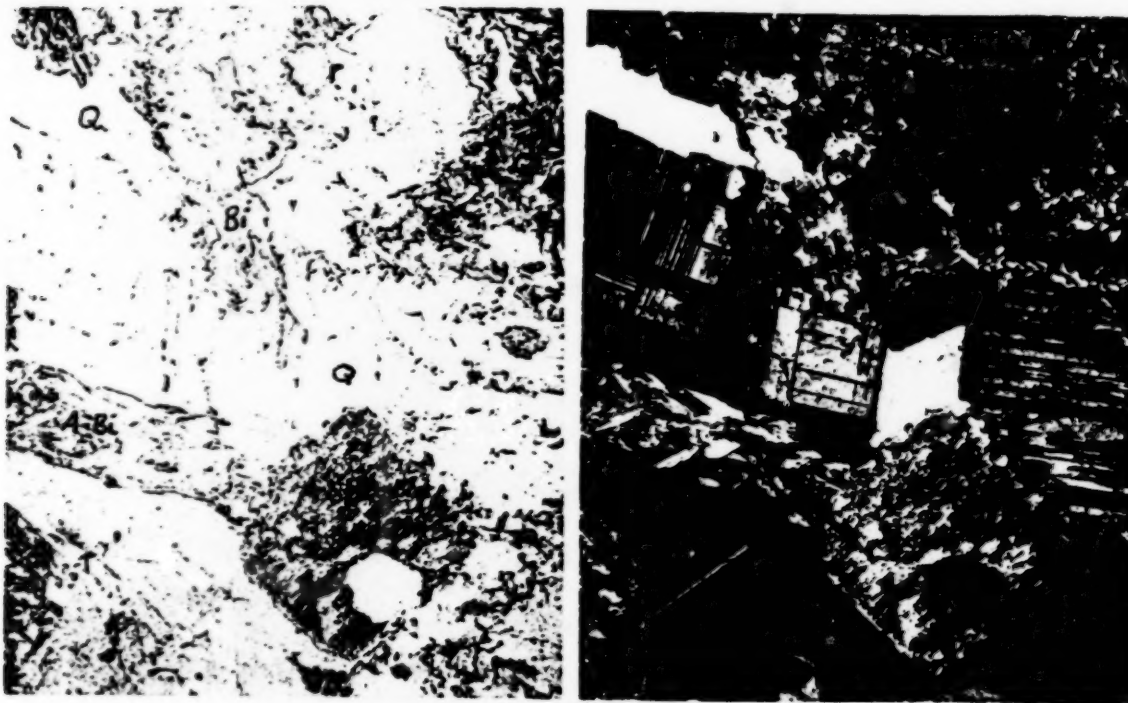


Figure 4. Quartz diorite in sample CB-32, mineralogically similar to CA-42, showing different amphibole-quartz-magnetite intergrowths; one (with Mg) appears to be pseudomorphous after pyroxene. Magnification 30x.

SAMPLE CB-46 (Sections LS-18-77, LS-19-77)

The sample is greenish grey quartz diorite similar to CB-32 but of coarser grain size. Blue quartz augen are scattered widely; ilmenite-magnetite crystals are common, mostly with biotite; and sulphides are finely dispersed locally in the specimens. Amphibole and biotite are more common in primary subhedral crystals than in intergrowths with quartz.

SAMPLE CB-59 (Sections LS-20-77, LS-21-77)

The specimen is medium to coarse grained quartz diorite, similar to that of sample CA-93 but paler, containing more plagioclase and scapolite. Blue quartz augen are scattered, as CB-46, and intergrowths of the ferromagnesianes are as abundant as primary crystals. Fractures and chloritic seams are more common than in CB-46.

SAMPLE CB-74 (Section LS-24-77)

The rock is medium grained quartz diorite megascopically identical to CB-32 except that biotite is slightly coarser and makes the mass slightly darker. Amphibole occurring as primary crystals may contain fine unoriented, poikilitic biotite intergrowths (as Fig. 4). Sulphides are scattered sparsely in many places. A lightly fractured zone is present at the 79-82 footage interval.

SAMPLE CB-94 (Sections LS-22-77, LX-23-77)

This sample is similar in appearance, composition and grain size to the quartz diorite in sample CB-74; scapolite is more common locally. Intergrowths of the ferromagnesianes are as abundant as primary monocrystals. Calcite-filled fractures and slickensided chloritic shears are rare.

SUMMARY AND CONCLUSIONS

The rock mass represented by these two drill cores is megascopically homogeneous, compositionally similar and varies little in texture and structure. Gradational changes in grain size and content of the minerals, particularly the proportions of feldspar and the ratio of primary to secondary ferromagnesian, changes the appearance of the rock slightly. The modal analyses show that the rock is predominantly quartz diorite, as the plagioclase is less calcic than normal for gabbro or norite and the quartz content is high for diorite. Pyroxene and olivine are absent in the sections studied, although many of the amphibole-biotite-quartz intergrowths may have been derived from them by deuteric alteration.

Joints and hairline fractures are widely spaced in the cores and often sealed with carbonates or quartz. Shears are rare, mostly chloritized and occasionally slickensided, and intergranular fracturing is uncommon. The only indication of strain in the rock, despite the prior suggestion of a high horizontal stress, is local slight warping of quartz, feldspar and amphibole crystals. Thus, the rock seems to be in a stable geological environment. Most of the core appears to have a low permeability, but in-situ testing is necessary to determine the permeability of the total mass.

The thermal behaviour of the rock should not differ greatly from specimen to specimen, excluding the minor effects of local discontinuities such as shears or fractures. Its thermal expansion, conductivity and diffusivity could be similar to that of gabbroic rock except that the quartz content may shift the values slightly from the known values for gabbro^(8,9). The amphibole-biotite-quartz intergrowths may also affect the parameters differently than the discrete primary crystals of the ferromagnesian silicates.

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TABLE 1

Mineralogical Compositions and Grain Sizes of
Creighton Mine Core Specimens CA and CB

Minerals	Proportions (Vol %) and Size Ranges (mm)							
	CA-42	CA-66	CA-79	CA-93				
	%	%	%	%				
	mm	mm	mm	mm				
Plagioclase (An)	(40) 45	0.2-3	(38) 40	0.2-4	(43) 45	0.1-4	(42) 47	0.2-8
Amphibole*	31	0.1-3	29	0.05-3	27	0.05-3	28	0.5-5
Quartz*	11	0.1-2	10	0.02-2	9	0.05-3	12	0.1-2
Biotite	9	0.2-2	15	0.2-5	12	0.5-5	8	0.5-5
Green Mica, Chlorite	1	0.2-3	<1	0.02-2	<1	0.1-1	1	0.1-1.5
Scapolite	<1	0.05-5	4	0.01-1	6	0.05-1	1	0.1-1
Ilmenite, Magnetite	2	0.05-2	1	0.01-3	<1	0.01-2	3	0.01-3
Apatite, Epidote Calcite, Sphene etc.	<.5	0.1-1	Negl.	0.05-2	<.5	0.01-1	Negl.	0.1-1
	CB-32	CB-46	CB-59	CB-74	CB-94			
	%	%	%	%	%			
	mm	mm	mm	mm	mm			
Plagioclase (An)	(38) 40	0.1-3	(43) 38	0.1-3	(39) 45	0.2-6	(41) 43	0.2-4
Amphibole*	31	0.1-3	27	0.02-4	15	0.3-10	30	0.1-10
Quartz*	9	0.02-5	16	0.01-4	16	0.1-5	12	0.05-5
Biotite	14	0.1-5	15	0.02-5	10	0.2-8	12	0.1-6
Green Mica, Chlorite	<1	<.4	<.5	0.01-1.5	<.5	0.01-2	<.5	0.01-1
Scapolite	4	0.03-1	2	0.01-2	11	0.02-2	1	0.01-2
Ilmenite, Magnetite	1	0.01-2	1	0.01-3	2	0.01-4	1	0.01-2
Apatite, Epidote, Sphene, Calcite etc.	<.2	<.1	0.3	0.01-1	0.5	0.05-2	0.5	0.02-5

* Includes proportions in metacrysts. (An) = Anorthite content.

TABLE 2
Abridged Petrographic Details of Drill Cores
From Test Site on 2300 Level, Creighton Mine

Footage, ¹ Sample	Description
<u>Core A</u>	
0-50 (CA-42)	Med. grained, greenish grey quartz diorite, megascopically homogeneous; rare fractures and shears, often sealed with calcite or chloritized mylonite
50-70 (CA-66)	Med. grained, dark greenish grey quartz diorite; biotite more abundant, than CA-42; rare chloritized shears, one adjacent to quartz vein; scattered sulphides
70-90 (CA-79)	Med. to coarse grained, grey to greenish quartz diorite, similar to CA-42, scapolite more common, primary ferromagnesian more abundant than intergrowths
90-122 (CA-93)	Coarse to med. grained, pale greenish grey quartz diorite; scattered large quartz augen, few intergrowths of ferromagnesian minerals; chloritic seam at 94
<u>Core B</u>	
0-35 (CB-32)	Med. grained, greenish grey quartz diorite; abundant biotite, quartz augen, sparse sulphides; rare quartz-sealed fractures, one unsealed; discing at CB-15, 17
35-50 (CB-46)	Med. grained dark grey quartz diorite; quartz more common, esp. augen, scattered sulphides; ferromagnesian mostly primary crystals
50-65 (CB-59)	Med. to coarse grained, paler grey quartz diorite, as CA-93 with amphibole content lower, andesine/scapolite high; fractures and chloritic seams more abundant
65-85 (CB-74)	Med. (to coarse) grained, greenish grey quartz diorite, similar to CB-32; scattered quartz augen, multi-crystal biotite masses; fracture system at 79-82
85-100 (CB094)	Similar to CB-74, slightly paler with more scapolite; fracturing and shearing uncommon, rare mafic seams

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